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TITLE: METHOD AND SYSTEM FOR INTER-WORKING AN ANSI TYPE
RADIO ACCESS NETWORK IN THE INTERNET PROTOCOL
BASED CORE NETWORK

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METHOD AND SYSTEM FOR INTER-WORKING AN ANSI TYPE RADIO ACCESS NETWORK IN THE INTERNET PROTOCOL BASED CORE NETWORK

BACKGROUND OF THE INVENTION

1. Field of the Invention

[1] The present invention relates to a mobile communication network, and more particularly to a method and system for inter-working an ANSI type radio access network (RAN) in an Internet Protocol (IP) based core network (CN).

2. Background of the Related Art

[2] The mobile communication network introduced in "TIA/EIA 3G-IOS V4.0.0 V&V Draft 5 Nov 1999" is composed of a RAN and a CN, each of which is further composed of functional network components for providing mobile communication service. Here, the term IOS (Inter-Operability Specification) is a matching protocol between a Base Station Controller (BSC) and a Mobile Switching Center (MSC). IOS is a radio communication application protocol for conducting call connection and disconnection functions for mobile communication service subscribers.

[3] The CN is established primarily with a circuit switching system based upon time division multiplexing (TDM). The network components that make up the CN are

associated with one another with the CN's physical connection and the logical matching protocol.

[4] Thus, a matching standard of a RAN depends on the structure of the relevant CN. A related art CN and RAN are matched by the common-channel signaling method (No. 7) on the TDM based circuit connection.

[5] Figure 1 illustrates related art stacks of matching protocols between a CN and a RAN. As shown in Figure 1, in a voice switching service, the CN, which includes a mobile communication network described in "TIA/EIA 3G-IOS V4.0.0 V&V Draft 5 Nov 1999," is constructed with a circuit switching network based upon the TDM of the synchronous transfer mode (STM). The CN is connected to the RAN through the trunk line matching based upon the G. 703 pulse code modulation (PCM).

[6] To provide the mobile communication switching service, the signal connection between the CN and the RAN is made through a signal network by the narrow band common-channel signal method (Narrow Band No. 7). Furthermore, the mobile communication call is connected using the IOS for the traffic connection. The voice switching service is provided using the TDM technique of the circuit switching method.

[7] On the other hand, for a data switching service, the CN and the RAN are connected with each other through high-speed packet network matching based upon the Internet Protocol (IP). In other words, for data communication, the radio

communication data service is provided using the packet routing technique. Accordingly, different communication networks are established with the CN for the voice switching and for the data service. Thus, user service is provided through dual CN structures.

[8] The related art has various disadvantages. For example, because the CN is constructed based upon the circuit switching network of the STM for the radio communication service, the CN conducts signal transmission control using the narrow band common-channel signal method for the purpose of matching with the RAN, and traffic transfer is made using the circuit transmission based upon TDM. Thus, for the transmission of non real-time transfer objects, such as packets or circuit data, the resource may be wasted due to the ordinary occupation of the virtual circuit.

[9] Furthermore, the basic transfer objects within the RAN are packet-based. However, in order to conduct the inter-working with the CN, an additional process of converting packets for the circuit is required. Accordingly, a complex protocol is required to separately control voice data and packet data.

[10] Also, because the radio communication CN establishes different communication networks for voice switching service and for the data switching service, the dual access method causes burdensome overheads in the CN operation.

[11] Additionally, in order to inter-work the voice switching CN with a packet network such as the Internet, a separate inter-working function (IWF) is necessary and a complex control protocol is required.

[12] The above references are incorporated by reference herein where appropriate for appropriate teachings of additional or alternative details, features and/or technical background.

SUMMARY OF THE INVENTION

[13] An object of the invention is to solve at least the above problems and/or disadvantages and to provide at least the advantages described hereinafter.

[14] Another object of the present invention is to provide a unified network integrating a RAN and a CN.

[15] Another object of the present invention is to provide a method and a system for signal connection and traffic transmission connection required for matching a RAN and a CN.

[16] It is another object of the present invention to provide a method and a system for inter-working an ANSI type radio access network (RAN) in the Internet Protocol (IP) based core network (CN).

[17] It is another object of the present invention to provide a method and a system for matching primary network components such as the mobile switching center (MSC) and the base station controller (BSC) so as to inter-work an ANSI Type RAN in the IP based CN, while causing minimum modifications in the currently operated ANSI

type RAN and establishing the IP based CN for accommodating the IP based ANSI type RAN.

[18] Another object of the present invention is to establish a RAN and a CN with the IP based communication network and thereby to provide the CN, wherein the transfer path between the RAN and the CN is based upon the general technology such as the IP, making it easy to construct a system and inducing cost reduction.

[19] Another object of the present invention is to accommodate the RAN directly within the IP based technology without using any separate inter-working function (IWF) device for the wireless Internet service.

[20] In order to achieve at least the above objects in a whole or in part, there is provided a method for inter-working a RAN in the IP based CN including making a traffic connection between a mobile station (MS) at the caller side and a BSS-IP at the caller side using a pre-determined protocol upon receiving a call connection request message from the MS at the caller side; interpreting a directory number (DN) of the MS at the call receiver side as requested by the caller MS and making a traffic connection between the MS at the call receiver side and the BSS-IP at the call receiver side using a pre-determined protocol; generating a ring-back tone using a pre-determined protocol so that the MS at the caller side may receive the ring-back tone; and discontinuing the ring-back tone using a pre-determined protocol if the MS at the call receiver side responds and establishing the call connection between the MS at the caller side and the MS at the call

receiver side. The pre-determined protocols preferably include the matching signal protocols for the signal connection transfer and the traffic connection control protocols. The matching signal protocols preferably include M3UA (MTP3 User Adaptation), SCTP (Stream Control Transmission Protocol), IP, MGCP (Media Gateway Control Protocol), IOS Application, SCCP (Signaling Connection Control Protocol), UDP (User Datagram Protocol), LLC (Logical Link Control) and Physical. The traffic connection control protocols include RTP (Real Time Protocol)/RTCP (Real Time Control Protocol), UDP, IP, Voice Encoded Data, LLC, MAC and Physical.

[21] Preferably, the step of making the traffic connection between the MS at the caller side and the BSS-IP at the caller side includes the steps of the wireless call agent (WCA)'s receiving a call connection request message transmitted from the MS at the caller side through the BSS-IP at the caller side (BSS-IP1); interpreting the DN of the MS at the call receiver side as requested by the MS at the caller side; transmitting a connection request message to the BSS-IP at the caller side using the MGCP if the DN is determined valid; assigning traffic connection ports to the IP network of the currently connected MS at the caller side and then transmitting a response message to the WCA; transmitting a resource assignment message to the BSS-IP at the caller side using the UDP port number; and confirming the completion of the traffic connection to the MS at the caller side and then transmitting a response message to the WCA.

side to a ring-back tone traffic channel; connecting the IP traffic port of the MS at the caller side to the ring-back tone traffic channel and then transmitting a response message to the WCA; transmitting to the BSS-IP at the caller side a modification connection request message together with the user traffic's voice message transcoding method and the protocol information for the end-to-end real-time message processing, using the previously assigned user ports; modifying the connection traffic path of the MS at the caller side to a ring-back tone traffic channel; connecting the IP traffic port of the MS at the caller side to the ring-back tone traffic channel and then transmitting a response message to the WCA; transmitting a notification request message to the tone source using the MGCP; and generating the ring-back tone through the traffic channel of the currently connected MS by referring to the notification request message and then transmitting a response message to the WCA.

[24] Preferably, the step of establishing the call connection between the MS at the caller side and the MS at the call receiver side includes the steps of transmitting a connection message from the MS at the call receiver side to the WCA through the BSS-IP at the call receiver side using the IOS message; transmitting a notification request message to the tone source using the MGCP; stopping the generation of the ring-back tone which has been transmitted and then transmitting a response message to the WCA; transmitting a connection delete message to the tone source; disconnecting the tone connection path on the IP network and then transmitting a response message to the WCA; transmitting

a modification connection request message to the BSS-IP at the caller side together with the user traffic UDP port number of the BSS-IP at the call receiver side, voice message transcoding method on the user traffic and the protocol information for the end-to-end real-time message processing; connecting the IP network traffic channel of the MS at the caller side under its management to the user traffic channel of the BSS-IP at the call receiver side and transmitting a response message to the WCA; and transmitting the connection message to the MS at the caller side and thereby establishing the call connection between the MS at the caller side and the MS at the call receiver side.

[25] In order to further achieve at least the above objects in whole or in parts, there is provided a system for inter-working a RAN in an IP based CN, including a WCA for conducting call connections and routing functions by controlling all gateways accommodated in the IP based CN; a BSS-IP (Base Station Subsystem for Internet Protocol) for conducting gateway functions by controlling the RAN and communicating with the WCA; a TG (Trunk Gateway) for conducting the voice traffic matching functions between the IP based CN and the conventional wire network and providing service functions unique to the voice communication; an SG (Signaling Gateway) for providing No. 7 signal connection matching function between the IP based CN and the conventional wire network; an HLR (Home Location Register) for managing mobile communication subscribers' locations within the mobile communication network and conducting the mobility control; and a PDSN (Packet Data Serving Node) for conducting

the inter-working of the IP network and the mobile communication CN so as to provide packet data services for the mobile communication subscribers.

[26] Preferably, the IP based CN may be routed by the IP based upon the connection of the ATM (Asynchronous Transfer Mode) or a high-speed packet network.

[27] Preferably, in between the BSS-IP and the WCA are matching signal protocol stacks for the signal connection transfer. In between the BSS-IP and TG are traffic connection control protocol stacks.

[28] Preferably, the matching signal protocol stack matches protocols below the MTP3 layer with the M3UA, SCTP and IP, adds the MGCP for controlling the BSS-IP's status and connection, and includes the IOS Application, SCCP, UDP, LLC, MAC and Physical.

[29] Preferably, the traffic connection control protocol stack adds the RTP/RTCP, UDP and IP for the voice traffic transfer and includes the Voice Encoded Data, LLC, MAC and Physical.

[30] In order to further achieve the above objects in whole or in parts, there is provided a system for inter-working a RAN in an IP based CN, including protocols for establishing the signal connection and the traffic transmission connection required for the matching of the two networks, wherein such protocols include an M3UA for conducting the matching function between the MT3 protocol which transfers messages on the conventional wire No. 7 signal network and the IP network; the SCTP for transferring

signal messages on the IP based network with reliability; the LLC for conducting the control function of the link level on the Internet; the MGCP for conducting the gateway control function required for physical matching the conventional PSTN and the IP network; the UDP for transferring [non-connection type higher level application messages] on the IP network; the IP to be used as the message routing basis on the Internet; and the MAC for conducting the control function of the physical link level on the Internet. Here, the MGCP is additionally used for the status control of the BSS-IP and the connection control of the traffic from the BSS-IP to the IP based network.

[31] Preferably, the certain protocols for conducting the signal connection further include the IOS Application for conducting the call connections and disconnections for mobile communication subscribers; and the SCCP for conducting the reliable signal data transfer function with respect to the higher level application signal protocols.

[32] Preferably, the certain protocols for conducting the traffic transmission connection further include the RTP/RTCP for conducting the control and transfer functions required for transferring real-time messages on the IP based network. Here, the RTP/RTCP is conducted so as to facilitate the traffic transfer and is executed based upon the UDP and IP.

[33] Additional advantages, objects, and features of the invention will be set forth in part in the description which follows and in part will become apparent to those having

ordinary skill in the art upon examination of the following or may be learned from practice of the invention. The objects and advantages of the invention may be realized and attained as particularly pointed out in the appended claims.

BRIEF DESCRIPTION OF THE DRAWINGS

[34] The invention will be described in detail with reference to the following drawings in which like reference numerals refer to like elements wherein:

[35] Figure 1 illustrates a related art inter-working protocol stack of a Radio Access Network (RAN) and a Core Network (CN).

[36] Figure 2 is a diagram illustrating the structure of the system for inter-working a RAN in the IP based CN according to a preferred embodiment of the present invention.

[37] Figure 3 illustrates matching signal protocol stacks of the RAN and the CN of Figure 2.

[38] Figure 4 illustrates matching traffic protocol stacks of the RAN and the CN of Figure 2.

[39] Figure 5 is a flow chart illustrating the method for inter-working a RAN in the IP based network according to a preferred embodiment of the present invention.

DETAILED DESCRIPTION OF PREFERRED EMBODIMENTS

[40] Reference will now be made to preferred embodiments of the present invention as illustrated in the accompanying drawings. As described below, a method and a system is provided for matching primary network components, such as the mobile switching center (MSC) and the base station controller (BSC), so as to inter-work an ANSI Type RAN in an IP based CN, while causing minimum modifications in the currently operated ANSI type RAN and establishing the IP based CN for accommodating the IP based ANSI type RAN.

[41] Figure 2 illustrates the structure of a system for inter-working a RAN in the IP based CN according to a preferred embodiment of the present invention. The system preferably includes a Wireless Call Agent (WCA) 10 for conducting call connections and routing functions by controlling all gateways accommodated in the IP based CN, such as a Radio Access Network Controller (RNC), and a Base Station Subsystem for Internet Protocol (BSS-IP) 20 for conducting gateway functions by controlling the RAN and communicating with the WCA 10. The system also preferably includes a Trunk Gateway (TG) 30 for conducting voice traffic matching functions between the IP based CN and the conventional wire network such as a PSTN (Public Switched Telephone Network), and providing service functions unique to voice communication, such as tone or announcement broadcast and so forth. A Signaling Gateway (SG) 40 is provided to match the No. 7 signal connection between the IP based CN and a wire network such as a PSTN, and an HLR 50 is provided for managing mobile communication subscribers'

locations within the mobile communication network and conducting the mobility control. The system also preferably includes a PDSN 60 for conducting the inter-working of the IP network and the mobile communication CN so as to provide packet data services for the mobile communication subscribers.

[42] According to the preferred embodiment, the WCA 10, which controls mobile calls in the IP based CN, and the BSS-IP 20, which controls the RAN and inter-working with the IP based CN, are major network components. The WCA 10 and the BSS-IP 20 are, respectively, comparable to the related art MSC and BSC. The structures of the WCA 10 and the BSS-IP 20, however, are different from those of the MSC and BSC. Thus, the IP based CN may be routed by the IP in accordance with the connection of the ATM (Asynchronous Transfer Mode) or a high-speed packet network, such as the Fast Ethernet.

[43] The preferred embodiment provides a network structure and matching protocols so as to conveniently provide IP network services, such as Internet services, by efficiently connecting the RAN with the IP based CN. In particular, new inter-working protocol stacks between the RNC and the MSC are suggested in the preferred embodiment.

[44] The protocol stacks between the BSS-IP 20 and the WCA 10 preferably include the related art matching protocols between the BSS and the MSC, which correspond to "A1" of the matching standards recommended in "TIA/EIA 3G-IOS V4.0.0

V&V Draft 5 Nov 1999." To transfer a call control message or a traffic message of mobile devices, however, the methods for signal transfer and traffic transfer based upon the IP are required.

[45] Thus, the matching signal protocol stacks shown in Figure 3 are preferably provided for the signal connection transfer. To operate the conventional "A1" matching protocol stack based upon the IP, protocols below the MTP3 layer in the signal connection control protocol stack are preferably matched with the M3UA, SCTP, and IP layers. For the control of the status and connection control of BSS-IP 20, the Media Gateway Control Protocol (MGCP) is preferably added. The M3UA preferably inter-works with the MTP3 protocol to conduct the message transfer function on a wire-based No. 7 signal network, and also inter-works with the IP network.

[46] The SCTP preferably conducts the function of reliably transferring signal messages on the IP based network. The IP is the protocol used as the message routing basis on the Internet. The MGCP preferably conducts the gateway control function required for the physical matching function between the PSTN and the IP network.

[47] Additionally, the matching signal protocol stack preferably includes the IOS Application for performing call connection and disconnection for mobile communication subscribers, the SCCP for conducting the reliable signal data transfer function with respect to the higher level application signal protocols, and the UDP for transferring non-connection type higher level application messages in the IP network. The matching signal

protocol also preferably includes the LLC for conducting the link level control functions on the Internet, the MAC layer for conducting the physical level control functions on the Internet; and the Physical layer.

[48] As shown in Figure 4, the traffic connection control protocol stacks of the preferred embodiment include RTP/RTCP, UDP, and IP for the voice traffic transfer instead of the related art circuit matching based upon the TDM. The RTP/RTCP performs the control and transfer functions required for transferring real-time messages, such as voice, on the IP based network. Additionally, the traffic connection control protocol stacks include the Voice Encoded Data, LLC, MAC, and the Physical layer.

[49] Consequently, the preferred embodiment includes the IP based signal protocols and the gateway control protocols for controlling and matching the RAN to the conventional mobile call control protocol stacks composed of the circuit based signal protocols. For the higher-level application protocols, the preferred embodiment may use the related art mobile control protocol for the compatibility.

[50] For the signal message transfer of mobile devices, the BSS-IP 20 and the WCA 10 preferably use the related art higher-level application protocols without modification. With respect to the lower level signal transfer protocols, messages are preferably transferred through the high-speed physical connection. They are matched with the M3UA, which performs the message conversion processing functions, based

upon the SCCP, the SCTP, which is the IP based common signal transfer protocol, and the IP.

[51] For the status control of the BSS-IP 20 and the traffic connection control from the BSS-IP 20 to the IP based network, the gateway control protocol MGCP is additionally used. In order to facilitate the traffic transfer, such as the voice transfer, the RTP/RTCP's real-time traffic transfer and control functions are conducted. The RTP/RTCP is conducted upon the UDP and the IP.

[52] Figure 5 is a flow chart illustrating the method for inter-working a RAN in the IP based CN according to a preferred embodiment of the present invention. First, a call connection request message, which is an IOS message (CM Service Req. [IOS]), is transmitted from an originating MS (MS1) to the WCA through an originating BSS-IP (BSS-IP1). Then, the WCA, having received the call connection request message (CM Service Req. [IOS]) from the MS1, preferably interprets the directory number (DN) of the receiving MS (MS2) as requested by the MS1.

[53] If it is determined that the DN interpreted by the WCA is valid, the WCA transmits a connection request message (CRCX [MGCP]) to the BSS-IP1 using the MGCP. The MS1 may thus assign an IP network traffic port (UDP Port) for the connection with the call receiving side later.

[54] Then, the BSS-IP1 assigns a traffic connection port to the IP network for the MS1, and generates a response message (Response [MGCP]) regarding such assignment. The BSS-IP1 transmits the response message to the WCA.

[55] The WCA transmits a resource assignment request (Assignment Req. [IOS]) to the BSS-IP1 so as to enable the physical traffic connection path and various information connection paths to be established between the BSS-IP and the MS1. Here, of the conventional IOS message information components, the UDP port number is preferably used instead of the circuit identity code (CIC).

[56] The BSS-IP1 then confirms whether the traffic connection with the MS1 has been completed, and transmits an IOS response message (Assignment Comp. [IOS]) to the WCA if the traffic connection has been completed.

[57] The WCA interprets the call receiving number and preferably transmits an IOS paging message (Paging Request [IOS]) to the MS2 through a receiving BSS-IP (BSS-IP2) associated with the MS2.

[58] Then, the MS2 recognizes the paging message (Paging Request [IOS]) and transmits an IOS message (Paging Response [IOS]) to the WCA through the BSS-IP2. This informs the WCA that the MS2 has been paged.

[59] Thereupon, the WCA assigns the UDP port to the BSS-IP2 associated with the MS2 so that the traffic with the originating side may be established. The WCA also

transmits an MGCP message (CRCX [MGCP]) to the BSS-IP2 to request the IP network's available connection port (UDP port).

[60] The BSS-IP2 then assigns the traffic connection port of the MS 2 and transmits a response message (Response [MGCP]) to the WCA.

[61] The WCA transmits a resource assignment request IOS message (Assignment Req. [IOS]) to the BSS-IP2 for the physical traffic connection path and various information connections between the BSS-IP2 and the MS2. Here, of the IOS message information components, the UDP port number is used instead of the CIC.

[62] Then, the BSS-IP2 confirms whether the traffic connection with the MS2 has been established and transmits an IOS response message (Assignment Comp. [IOS]) to the WCA if the traffic connection has been completed.

[63] The WCA preferably next transmits an IP network traffic connection request message (CRCX [MGCP]) to the tone source using the MGCP so that the MS1 may receive a ring-back tone indicating that the call receiving side is being paged. Here, the IP traffic UDP port number of the MS1 is transmitted as well, so as to enable the tone connection. Moreover, the information relating to the voice message transcoding method on the user traffic and the protocol (RTP/RTCP) for the end-to-end real time message processing is preferably transmitted as well.

[64] The tone source accommodates the WCA's request and modifies the MS1's connection traffic path to the ring-back tone traffic channel, thereby connecting the IP

traffic port of the MS1 with the tone traffic channel. Then, the tone source transmits a response message (Response [MGCP]) to the WCA.

[65] The WCA preferably transmits an MGCP modification connection request message (MDCX [MGCP]) to the BSS-IP1 using the previously assigned user port for the IP traffic connection request with the tone source so as to enable the MS1 to hear the ring-back tone. With the message, information relating to the voice message transcoding method on the user traffic and the protocol (RTP/RTCP) for the end-to-end real time message processing is preferably transferred as well.

[66] Next the BSS-IP1 accommodates the WCA's request and modifies the MS1's connection traffic path to the ring-back tone traffic channel, thereby connecting the MS1's IP traffic port with the ring-back tone traffic channel. The BSS-IP1 then transmits a response message (Response [MGCP]) to the WCA.

[67] The WCA preferably transmits a notification request message (RQNT [MGCP]) using the MGCP to the tone source so that the ring-back tone may be transmitted to the MS1. The tone source generates the ring-back tone through the traffic channel of the MS1 by referring to the notification request message (RQNT [MGCP]) received from the WCA, and transmits a response message (Response [MGCP]) to the WCA.

[68] From this point, the MS1 and the BSS-IP1 process the audio message during the tone generation period, thereby receiving the ring-back tone indicating that MS1 is paging the call receiving side.

[69] If the MS2 responds to the paging signal, the MS2 preferably transmits a connection message (CONNECT [IOS]) to the WCA through the BSS-IP2 to indicate that it has replied to the call. The WCA recognizes such response message of the MS2 and preferably transmits a notification request message (RQNT [MGCP]) using the MGCP to the tone source to stop the ring-back tone transmission to the originating side. The tone source thus stops the generation of the ring-back tone, and then transmits a response message (Response [MGCP]) to the WCA.

[70] The WCA preferably next transmits a connection deletion message (DLCX [MGCP]) to the tone source to disconnect the IP network connection traffic on the tone source, which was made for the transmission of the ring-back tone. Thereupon, the tone source disconnects its existing tone connection path upon the IP network and transmits a response message (Response [MGCP]) to the WCA.

[71] Thereafter, for the IP network traffic connection between the MS2 and the MS1, the WCA preferably transmits an MGCP modification connection request message (MDCX [MGCP]) to the BSS-IP1 so as to modify the ring-back tone connection path to the BSS-IP2's traffic channel. The BSS-IP2's user traffic UDP port number and the information relating to the voice message transcoding method on the user traffic and the

protocol (RTP/RTCP) for the end-to-end real time message processing is transmitted as well.

[72] The BSS-IP1, in compliance with the WCA's request, preferably connects the MS1's IP network traffic channel to the BSS-IP2's user traffic channel and then transmits a response message (Response [MGCP]) to the WCA.

[73] Then, the WCA transmits an IOS connection message to MS1, indicating that the MS2 has responded to the call. Consequently, the call connection between the MS1 and the MS2 is established.

[74] As explained above, the preferred embodiment of the present invention has many advantages. For example, the preferred embodiment provides a unified communication network by matching the RAN and the CN based upon the IP, and provides a method and system for the signal connection and traffic transfer connection required for the network matching. As a result, a CN may be established, having the transfer path between a RAN and the CN based upon the common technology such as the IP, facilitating the convenient construction of the system and saving the relevant costs.

[75] Furthermore, because the preferred embodiment accommodates a RAN directly into the IP basis, no separate conversion device is required for the wireless Internet service provision. Consequently, service may be provided with expediency and the high performance may also be achieved.

[76] The preferred embodiment of the present invention provides a unified communication network by matching the RAN and the CN based upon the IP and provides a method and a system for the signal connection and traffic transfer connection required for the network matching. As a result, a CN may be established, having the transfer path between a RAN and the CN based upon the common technology such as the IP, facilitating the convenient construction of the system and saving the relevant costs.

[77] Furthermore, because the present invention accommodates a RAN directly within the IP basis, no separate conversion device is required for the wireless Internet service provision. Consequently, the service may be provided with expediency and the high performance may also be achieved.

[78] The foregoing embodiments and advantages are merely exemplary and are not to be construed as limiting the present invention. The present teaching can be readily applied to other types of apparatuses. The description of the present invention is intended to be illustrative, and not to limit the scope of the claims. Many alternatives, modifications, and variations will be apparent to those skilled in the art. In the claims, means-plus-function clauses are intended to cover the structures described herein as performing the recited function and not only structural equivalents but also equivalent structures.